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Dynamic Modeling of Labor Migration Between Scientific Organizations

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Abstract: In this article we examine the processes of academic potential reproduction, taking into account the main threats from scientific migration. Historically, since the 1990-s the amount of researchers in Russian Federation decreased by 58%. Under these conditions it is necessary to estimate the scale of further scientific migration and the outflow of researchers to other spheres of economy. For this purpose we developed a synthetic construction of dynamic models of labor migration and proportional economic growth with two-level optimization. The basis of this model is presented by the classical problem of optimal investments into capital management, expanded by the control unit of total costs directed to the labor resources. This model construction allows us to describe the migration movement between scientific organizations and institutes, taking into account the difference in working conditions. The pricing mechanism in this model is based on the assumption of organization's output maximization at a fixed cost. As result we obtained a multi-level model for the prediction of scientific personnel migratory flows between organizations.

Keywords: dynamic modeling, games theory, positional games, proportional economic growth, labor market, labor migration, academic potential.

1. INTRODUCTION

Globalization is one of the main trends in the socio-economic system development and has both positive and negative effects. On the current stage it affects also the professional education system and the scientific field, and leads to significant changes for the process of scientific and academic potential reproduction. It is necessary to mention, that academic potential is one of the main drivers of scientific and technological progress due to a positive connection between the growth in the number of researchers and the rate of economic development (Docquier F., Rapoport H., 2011). Reproduction of the scientific and academic potential plays a key role in the re-industrialization of country's economic system, ensuring the economic security of the state and reducing threats to economic development.

The situation in Russia can be characterized by the trend, which consists in an increasing imbalance between the specifics of the functioning of the domestic economy and the human resources potential in the sphere of research and development, and the emigration of human capital (Kazantsev A.A., Borishpolets K.P., 2013). Taking into account the specifics of statistics, it is difficult to make an unambiguous conclusion about the size of the outflow of scientific personnel, not related to the migration of Russian scientists.

The level of innovative development of the education branch can be quantitatively assessed through a system of indicators, characterizing the conditions for the functioning and development of the industry. Different methods of estimation provide different results. Expert estimates also vary significantly: from 2 million in the first 10 post-Soviet years (Artyushina A.B., 2010) to about 30,000 Russian scientists permanently residing abroad and 120,000 working under temporary contracts (Ushkalov I., 2000).

Correct management of scientific funding can help to reduce the loss of high qualified human capital and increase the effectiveness of scientific organizations. When modeling the microeconomic system, it is necessary to describe the interactions between scientists and organizations at the microlevel, which suggests a description of the of scientific organizations development dynamics and the flows of labor migration between them (Tarasyev A.M., Tarasyev A.A., 2017).

2. THEORETICAL FRAMEWORK

Labor is one of the major components of production, which can be seen in both from micro- and macroeconomic point of view. Due to the specific of scientific migration, the official statistics has a certain degree of fragmentation, and there is no systematic approach to the economic and social consequences of scientific migration processes. To describe the economical factors of scientific migration between organizations we apply to the theory of economic growth. At the current stage economics provide two theories of economic growth: namely the neo-Keynesian economics and the neoclassical economics, which determines the use of the two types of models, that characterize these theories.

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At the heart of the neo-Keysian theory (Keynes J.M., 1936) lies the idea of relative instability of the market economy, as well as macroeconomic equilibrium. In addition, it should be noted that this scientific direction was formed also in accordance with the theory of A. Smith (Smith A., 1977).

Neoclassical direction is based on the idea of the equilibrium of the optimal market system, which is regarded as an ideal self-regulating mechanism. In a real economy, such an equilibrium is practically not attainable. However, when modeling the equilibrium, it becomes possible to correct the deviation of real economic processes from ideal ones. One of the first authors of neoclassical models of economic growth was Frank Plampton Ramsay. The Ramsey-Kassa-Kupmans model is a model of endogenous economic growth in which the trajectory of consumption and savings is determined on the basis of solving the problem of optimizing households and firms behavior in conditions of perfect competition.

Also, within the framework of the non-classical direction, the work of Robert Solow (Solow R.M., 1970) is of great importance for the development of the theory of economic growth. In his studies, R. Solow modified the Cobb-Douglas function, taking into account the additional factor in the model - the level of technology development. At the same time Solow assumed that some changes in the level of technology development contributes to the same increase in capital and labor. In the Solow model, technological progress is the main condition for achieving a permanent improvement in the living standard of the population, since only with continuous technological progress the growth of the fund-raising and output per employee is fixed.

Modeling of the migration processes dynamics between several organizations suggests a combination of a number of theories: the neoclassical concept of migration, the synthetic theory of migration D. Massey and the theory of human capital for explaining the socio-economic factors of labor resources attraction and expulsion.

In Keynesian economics, unit-labor cost is the most important factor in determining the price level in a closed economy (Herr H., 2009). It also says that, due to insufficient goods demand in the overall economy, any level of unemployment can be occurred. Another important driver of Keneysian mode of thinking is the price level changes in exchange rate. Under positive economic conditions nominal wage increases according to trend productivity growth, as well as the target inflation rate of the central bank, discretionary monetary policy geared towards growth and anti-cyclical fiscal policy.

The neoclassical theory of migration proceeds from the existence of free competition and a perfect market of the production factors. The basic model originally developed to explain migration in the process of economic development in the works of Hicks (Hicks J.R., 1963), Lewis (Lewis W.A., 1954) and Harris and Todaro (Harris J.R., Todaro M.P., 1970) highlights, that migration depends on the difference in the salaries levels for potential migrants at their home country and on the possible salaries after migration, which is caused by the uneven distribution and low efficiency of production factors. According to this theory and its extensions, the difference in wages should be sufficient to cover the costs of moving.

As a result, migration contributes to the equalization of salaries and to the stabilization of the world labor market by reducing the supply of labor in the labor market, which is excessively endowed with manpower and increasing the supply in the labor market, poor in manpower. The resulting difference in wages causes workers for migration. Under the assumption of full employment, it predicts a linear relationship between salaries difference and migration flows (Bauer and Zimmermann 1999; Massey et al. 1993; Borjas 1987). The person continues to look for work if the expected revenues are equal to the costs of searching, that is, while the first job offer is not optimal.This means that people often stay unemployed through a rational decision and continue to search (Stigler G.J., 1961).

The basic assumption of the microeconomic model of individual choice (Todaro M., 1969) is the decision to migrate, taken by a rational individual, based on the knowledge of the consequences of the move, related to costs and profits, and an estimate of the expected benefits from differentiation of income across the territories. Within the framework of the model of individual choice, migration processes appear as investments into human capital. In this case, the territory of arrival is chosen by the migrant in order to maximize his productivity, taking into account his qualification level.

A synthetic theory of migration, also known as the theory of migration networks, was proposed by the sociologist Douglas Massey (Massey D.A., 2002). This theory explains international migration by the prevalence of capitalist relationships in non-market societies. Massey included in the basis of his theory the position of the classical theory of migration. According to Massey's theory, in the process of making a decision on the need for migration and selection of the country of destination, the employee faces the problem of incomplete information about the labor market conditions and living conditions in other countries. The solution to this problem is facilitated by migration networks, which are understood as a set of interpersonal links that connect migrants, former migrants and potential migrants to each other through relationships of kinship, friendship and common social origin.

This combination allows to identify and explain the main factors of expulsion and attraction of migration flows.

3. LABOR MIGRATION DYNAMIC MODELING

The production function (Cobb C.W., Douglas P.H., 1928) has a number of properties that should be taken into account when compiling a proportional growth model: output is zero provide that at least one of the production factors is not used; release increases with an increase in the quantitative value of one of the factors; basic conditions for the law of decreasing marginal productivity of factors are fulfilled; with an increase in the use of one of the factors, the return on the increase in use in production of the second factor is increasing. The production function has a constant return on scale. We introduce the production function to describe the volume of output:

$$y(t)=a\cdot e^{bt}\cdot K^{\alpha}(t)\cdot L^{\beta}(t), \quad (1)$$

where *K(t)* - the value of the fixed assets of the organization;

L(t) - number of employees in the organization;

$a\cdot e^{bt}$ - total factor productivity, increasing exponentially and taking into account the factors implicit in the model, $\alpha\geq 0,\ \beta\geq 0,\ \alpha+\beta=1$.

Capital within this model corresponds to fixed assets, and labor resources determine the number of people employed in the organization. In this model, we assume that labor resources are subordinated to the classical dynamics, in which investment components, adjusted for the magnitude of the depreciation of the relevant factor, contribute to the growth of the indicators. Using the differential equation, we describe the dynamics of capital change in the classical form:

$$\frac{dK(t)}{dt}=s_K(t)\cdot y(t)-\delta_K\cdot K(t),\ K(0)=K_0, \quad (2)$$

where s_K - present investments into capital;

y(t) - is the total output of the organization;

$\delta_K\geq 0$ - level of depreciation of fixed assets *K(t)*.

With this task formulation, it is also necessary to express the share of investments, aimed at the development of fixed assets. We will express the share of investments in fixed assets $s_K(t)$ through investments, aimed at fixed assets $I_K(t)$ and the volume of output:

$$s_K(t)=\frac{I_K(t)}{y(t)}, \quad (3)$$

3.1 Pricing mechanism

The pricing mechanism in the model is given by means of the Cobb-Douglas production function:

$$p(t)=a_p\cdot y^{\alpha_p}(t)\cdot L^{\beta_p}(t), \quad \alpha_p>0;\ \beta_p<0 \quad (4)$$

where α_p, β_p are the control parameters, obtained when the model is calibrated. Due to this parameter, there is a regulation of wages in the market. In the classical formulation, the dynamics of labor resources is described by a differential equation:

$$\frac{dL(t)}{dt}=\frac{s_L(t)\cdot y(t)}{p(t)}-\delta_L\cdot\left(L(t)+x_{ij}(t)\right),\ L(0)=L_0, \quad (5)$$

where s_L - investment in labor resources;

p(t) - the price of labor resources, the level of wages;

$\delta_L\geq 0$ - level of depreciation for labor resources *L(t)*.

Within the framework of the model, the described dynamics of labor resources can be both positive and negative, depending on the socioeconomic situation, which develops in the system under consideration. The share of investments, directed to labor resources, is expressed by an indicator for which the following relationship is satisfied:

$$s_L(t)=\frac{I_L(t)}{y(t)}, \quad (6)$$

The total volume of investments in the presented model is determined by a function, that takes into account investments into capital and labor:

$$s(t)=s_K(t)+s_L(t), \quad (7)$$

The pricing mechanism in this model is presented as a player, who sets the labor resources price. Bringing the model parameters to relative values, allows expressing the rate of price growth and describing the dynamics of investment flows under conditions of proportional development of the described system.

3.2 Dynamics of migration flows between organizations

The dynamics of migration flows (Vasilyeva A.V., Tarasyev A.A., 2012) between scientific organizations is described by the following function:

$$x_{ij}(t+1)=x_{ij}(t)+\frac{\alpha_j\left(L_i-x_{ij}(t)\right)\left(p_j(t)-p_i(t)\right)}{L_i\cdot p(t)}dt, \quad (8)$$

where $p_i(t)$, $p_j(t)$ - the price of labor, the difference in wage levels between organizations, involved into the migration process;

$x_{ij}(t)$ - migration flow of labor migration of scientific workers;

L_i - the potential number of scientists, ready for migration.

The optimization task of the first level is to maximize the output volume, subjected to the availability of restrictions on total costs. The basic proportion determining the dynamics of interaction of capital and labor resources in this model allows to maximize the output volume at the given costs. To maximize the output, we need to maximize the value of the release function (1):

$$y(t)=a\cdot e^{bt}\cdot K^{\alpha}(t)\cdot L^{\beta}(t)\xrightarrow[K,L]{}\max, \quad (9)$$

It is necessary to take into account a number of limitations on the basic parameters of the model, that ensure adequate behavior of the considered system on the finite and infinite horizons. The parameter *C(t)* in this equation is positive determined and describes the total costs, specified in the model. Expenditures on the basic control parameters of the model, capital and labor resources are limited by the relation (9), which determines linear dependence on the total costs:

$$K(t)+p(t)\cdot L(t)=C(t), \quad (10)$$

3.3 Proportionality condition in the economic growth model

We consider the classical problem of microeconomics, an analytical solution of which can be obtained using the Lagrange method. For the optimization task of the first level of the model, the condition of proportionality between capital and labor resources is necessary to ensure a balanced state of the economic system in the model. The proportionality condition in the model is described by a relation, which allows to assess the degree of interaction between labor and capital, when the dynamics of wages in the system changes:

$$\frac{K}{L} = \frac{\alpha \cdot p(t)}{\beta}, \qquad (11)$$

In view of the homogeneity condition (2) given in the model, this relation (10) leads to the linearity of the optimal solution with respect to the total cost. Accordingly, we can express investments into capital and labor resources in relation to the total cost as follows:

$$K = \alpha \cdot C, \qquad (12)$$

$$L = \frac{\beta}{p(t)} \cdot C, \qquad (13)$$

$$y = A(t) \cdot C, \qquad (14)$$

$$A(t) = a \cdot \alpha^{\alpha} \cdot \left(\frac{\beta}{p(t)}\right)^{\beta}, \qquad (15)$$

3.4 Description of aggregated variables

With the help of the function *A(t)*, the share of output, obtained due to the factors, considered in the model indirectly, is determined. It should be noted that the total value in the model is considered as an aggregated variable *C(t)*, which is necessary for representing the solution of the optimization problem of the first level. The aggregated variable is transferred to the second level to solve the task of managing investments directed into capital and labor resources. The dynamics of aggregate value is calculated on the basis of relations (2) and (5), intended for describing the behavior of fixed capital and labor resources. In this case, the proportionality conditions given in model (11) - (15) are taken into account. As a result, the aggregated value is described by a differential equation of the form:

$$\frac{dC(t)}{dt} = C(t)\big(A(t) \cdot s(t) + r(t) - \delta\big), \; C(0) = K_0 + p_0 \cdot L_0 \,. \qquad (16)$$

The aggregated indicator of the price growth rate within the framework of the considered system is expressed through the rates of price growth specified for the main parameters of the economic growth model:

$$r(t) = \alpha \cdot r_K(t) + \beta \cdot r_L(t)\,. \qquad (17)$$

Since $r_K(t) = \frac{\dot{p}_K(t)}{p_K(t)} = 0$ and $r_L(t) = \frac{\dot{p}_L(t)}{p_L(t)} = \frac{\dot{p}(t)}{p(t)}$, where the parameters $\dot{p}_K(t)$ and $\dot{p}_L(t)$ express the derivatives of the prices for capital and labor, the derivative of the total price is expressed through $\dot{p}(t)$. As a result, the rate of price growth in the model can be expressed as follows:

$$r(t) = \beta \cdot \frac{\dot{p}(t)}{p(t)}\,. \qquad (18)$$

We express the aggregated level of depreciation, taken into account expression (15), provided that $\delta_K(t) = \delta_K$ and $\delta_L(t) = \delta_L$:

$$\delta = \alpha \cdot \delta_K + \beta \cdot \delta_L\,. \qquad (19)$$

Let us describe the dynamics of proportional growth of capital *K(t)* and labor resources *L(t)* with the known dynamics of aggregated costs within the limits of the proportionality conditions, given by the relationship (11) - (14). Dynamics of capital *K(t)* under conditions of proportional development is described by the following equation:

$$\frac{dK(t)}{dt} = K(t) \cdot \big(A(t) \cdot s(t) + r(t) - \delta\big), \; K(0) = K_0 \,. \qquad (20)$$

Investments into capital $s_K(t)$, represented in expression (3), can be derived through general investments *s(t)* in accordance with equation (20). This equation allows us to take into account the relationship between the rate of price growth and the aggregated level of depreciation for a certain volume of output:

$$s_K(t) = \alpha \cdot s(t) + \frac{\alpha}{A(t)} \cdot \Big(\big(r(t) - r_K(t)\big) - \big(\delta(t) - \delta_K(t)\big)\Big)\,. \qquad (21)$$

An equation describing the dynamics of labor resources under given proportional growth conditions, taking into account the price growth rate and the aggregate level of depreciation, is presented as follows:

$$\frac{dL(t)}{dt} = \big(L(t) + x_{ij}(t)\big) \cdot \Big(A(t) \cdot s(t) + \big(r(t) - r_L(t)\big) - \delta\Big)\,. \qquad (21)$$

The dynamics of investments into labor resources $s_L(t)$ is expressed through the value of total investment costs *s(t)*, similar to the above described behavior of investment flows directed into fixed assets:

$$s_L(t) = \beta \cdot s(t) + \frac{\beta}{A(t)} \cdot \Big(\big(r(t) - r_L(t)\big) - \big(\delta(t) - \delta_L(t)\big)\Big)\,. \qquad (23)$$

3.5 Dynamic optimization of economic indicators

In accordance with the design of the model, the solutions of the first level are aggregated into cost costs and transferred to the second level of optimization. Dynamic optimization of economic indicators is carried out at the second level with the help of the Pontryagin maximum principle (Pontryagin L.S., Boltyansky V.G., Gamkrelidze R.V., Mishchenko E.F., 1961). We use the integral logarithmic index of discount consumption, which can be represented by the following relationship based on the balance equation and the structure of the universal production function, with parameter *ρ* setting the discount rate:

$$J = \int_{t_0}^{T} e^{-\rho t} \Big(\ln A(t) + \ln C(t) + \ln\big(1 - s(t)\big)\Big) dt\,, \qquad (24)$$

Consider the problem of optimal control for investments at the second level of optimization. The parameter *σ(t)*, responsible for generalized depreciation of costs, is determined by the difference between the aggregated level of depreciation and the rate of price growth *σ(t)=δ(t)-r(t)*. At the second level of optimization, the problem of optimal control for investments is considered. This problem is characterized by the maximization of the utility function in a controlled system on the trajectories, obtained as a result of the description of the cost dynamics *C(t)*. As a result, the problem of optimal control will be presented as follows:

$$J\left(C(\cdot),s(\cdot),T\right)=\int_{t_0}^{T} e^{-\rho t}\left(\ln A(t)+\ln C(t)+\ln\left(1-s(t)\right)\right)dt \,. \quad (25)$$

The solution of this problem within the Pontryagin maximum principle is the optimal level of investments *s(t)* that links all the blocks of the model. The fulfillment of the necessary conditions for optimality makes it possible to obtain an optimal control structure that realizes the maximum of the Hamiltonian $\bar{H}(t,C,\psi)$:

$$s=\begin{cases} 0, & 1-\dfrac{1}{\psi(t)A(t)C(t)}<0 \\ 1-\dfrac{1}{\psi(t)A(t)C(t)}, & 0\le 1-\dfrac{1}{\psi(t)A(t)C(t)}\le s^0 \\ s^0, & 1-\dfrac{1}{\psi(t)A(t)C(t)}>s^0 \end{cases} . \quad (26)$$

The expressions, obtained for optimal control problem, determine in the model the structure of the maximized Hamiltonian, given by three paths. The first path corresponds to the zero extremal control mode, the second path represents the regular control mode, the third path is defined by the extreme mode of the maximum possible control level. This problem is characterized by the maximization of the utility function under the conditions of a controlled system on the trajectories, obtained as a result of the description of the systems dynamics, determined by the conditions of the Pontryagin maximum principle (Pontryagin L.S., Boltyansky V.G., Gamkrelidze R.V., Mishchenko E.F., 1961):

$$\begin{cases} \dot{C}(t)=C(t)\left(A(t)s_i(t)-\sigma(t)\right), \\ \dot{\psi}(t)=\rho\psi(t)-\dfrac{\partial H_i}{\partial C}\left(t,C(t),\psi(t)\right). \end{cases} \quad (27)$$

It should be noted that the solution of the Hamiltonian dynamics equation for generalized costs in the case of problems with a finite and infinite horizon is described by the relations $x(t)=\dfrac{1}{\rho}\left(1-e^{\rho(t-T)}\right)$ and $x(t)=\dfrac{1}{\rho}$.

$$s^*(t)=\begin{cases} 0, & 1-\dfrac{\rho}{A(t)\left(1-e^{\rho(t-T)}\right)}<0 \\ 1-\dfrac{\rho}{A(t)\left(1-e^{\rho(t-T)}\right)}, & 0\le 1-\dfrac{\rho}{A(t)\left(1-e^{\rho(t-T)}\right)}\le s^0 \\ s^0, & 1-\dfrac{\rho}{A(t)\left(1-e^{\rho(t-T)}\right)}>s^0 \end{cases} . \quad (28)$$

We obtain analytical relations for optimal control by substituting solutions of the equations of Hamiltonian dynamics into the structure of optimal control. When considering the problem on the final horizon, optimal control is set by the system (28).

When obtaining optimal investments $s^*(t)$, it is possible to reverse the transition from the second level of optimization to the first level, and also to determine the structure of the optimal investment flows aimed at providing labor resources in accordance with the conditions of the initial system. Due to the concavity property of the maximized Hamiltonian $\bar{H}(t,C,\psi)$ with respect to the variable *C*, the Pontryagin maximum principle identifies trajectories, that satisfy the optimality condition for the control problem (30) - (31) (Ane B.K., Tarasyev A.M., Watanabe C., 2007).

4. CONCLUSIONS

Globalization in the scientific, technical and educational spheres presupposes the creation of favorable conditions for the international mobility of the intellectual labor force and the opening of all markets for scientific workers by countries. In the modern form of scientific activity, the mobility of a scientist is one of the prerequisites for his successful scientific career.

In a society in which the migration of professionals is practically unlimited, stopping the outflow of one's own scientific personnel and attracting researchers from abroad are possible only through the development and implementation of advanced technological developments and large-scale innovative projects, which require international cooperation. The question remains, to what extent these tasks are comparable to the real state of the infrastructure of the sphere of research and development, and the true state of scientific personnel.

During periods of social transformations, Russian science carried enormous losses of scientific personnel - scientists traveled abroad, went to other spheres of activity. In many ways, the processes of emigration and the change in the sphere of activity were forced, and, of course, the human resources potential of science lost in the 1990s will not be filled up rapidly.

The developed model allows describing the dynamics of development of socio-economic systems with several management regimes and migration flows of scientific personnel between the systems. This approach is possible by integrating dynamic migration models into equations describing the dynamics of human capital, labor resources and scientific potential in the model of proportional economic growth. The resulting model can be used for econometric analysis and predictive modeling of sustainable development of countries and regions in the optimization of investment flows at the macro level and of firms, companies and scientific organizations at the micro level.

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REFERENCES

Ane B.K., Tarasyev A.M., Watanabe C. (2007). Construction of Nonlinear Stabilizer for Trajectories of Economic Growth. *Journal of Optimization Theory and Applications*. Vol. 134. No. 2. pp. 303-320.

Artyushina A.B. (2010). Actor-network theory in inaction. Strategies and limitations of anthropological research of the Russian laboratory. *Journal of Sociology and Social Anthropology*. No. 2. 100-115.

Bauer T.K., Zimmermann K.F. (1999). Assessment of possible migration pressure and its labour market impact following EU enlargement to Central and Eastern Europe. *IZA Research Report No. 3*

Borjas G.J. (1987). Self-Selection and the Earnings of Immigrants. *The American Economic Review*, Vol. 77. Is. 4. pp. 531–553.

Cobb C.W., Douglas P.H. (1928). A Theory of Production. *American Economic Review*, 18 (1): 139-165

Docquier F., Rapoport H. (2011). Globalization, Brain Drain and Development. *IZA Discussion Papers 5590*, Institute for the Study of Labor (IZA). - 60 p.

Harris J.R., Todaro M.P. (1970). Migration, Unemployment and Development: A Two- Sector Analysis. *The American Economics Review*, Vol.60. Is. l. pp. 126-142.

Herr H. (2008). The Labour Market in a Keynesian Economic Regime: Theoretical Debate and Empirical Findings. *Cambridge Journal of Economics*, Vol. 3, Is. 5, pp. 949-965.

Hicks J.R. (1963). The Theory of Wages. *London: Macmillan*, 1932, 2nd ed., 1963.

Keynes J.M. (1936). The General Theory of Employment, Interest and Money. London: Macmillan (reprinted 2007).

Kazantsev A.A., Borishpolets K.P. (2013). "The Brain Drain" from Russia as a Political and Administrative Problem. *Bulletin of MGIMO-University*. No. 6. 206-214.

Lewis W.A. (1954). Economic Development with Unlimited Supplies of Labor. *The Manchester School*, Vol. 22, No. 2, pp. 139-191.

Massey, D. S., Arango, J., Hugo, G., Kouaouci, A., Pellegrino, A., and Taylor, J. E. (1993). Theories of International Migration: Review and Appraisal. *Population and Development Review*, Vol. 19, Is. 3, pp. 431–466.

Massey D. A. (2002). Synthetic theory of international migration. *World in the mirror of international migration*, Vol. 10. pp. 143-153.

Pontryagin L.S., Boltyansky V.G., Gamkrelidze R.V., Mishchenko E.F. (1961). Mathematical theory of optimal processes. *Moscow: Fizmatgiz*. 391p.

Smith A. (1977). An Inquiry into the Nature and Causes of the Wealth of Nations. University of Chicago Press.

Solow R.M. Growth Theory: An Exposition. *NY, Oxford Univ. Press*, 1970.

Stigler, George J. (1961). The Economics of Information. *The Journal of Political Economy*, Vol. 69, pp. 213-225.

Tarasyev A.M., Tarasyev A.A. (2017). The gravity model of labor migration behavior. *AIP Conference Proceedings*, 1863, 560062.

Todaro M.P. (1969). A Model of Labour Migration and Urban Employment in Less Developed Countries. *American Economic Review*, Vol.59. pp. 138–148.

Ushkalov I. (2000). Intellectual emigration and security. *In the book: Migration and Security in Russia.* M .: Intrediatek. 128-130.

Vasilyeva A.V., Tarasyev A.A. (2012). Dynamic multiregional model of labour migration: Construction and realization. *Economy of Region*, Vol.4, pp. 149-157.